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Coordinated Ramping Product & Regulation Procurement in CAISO Using Probabilistic Solar Power Forecasts

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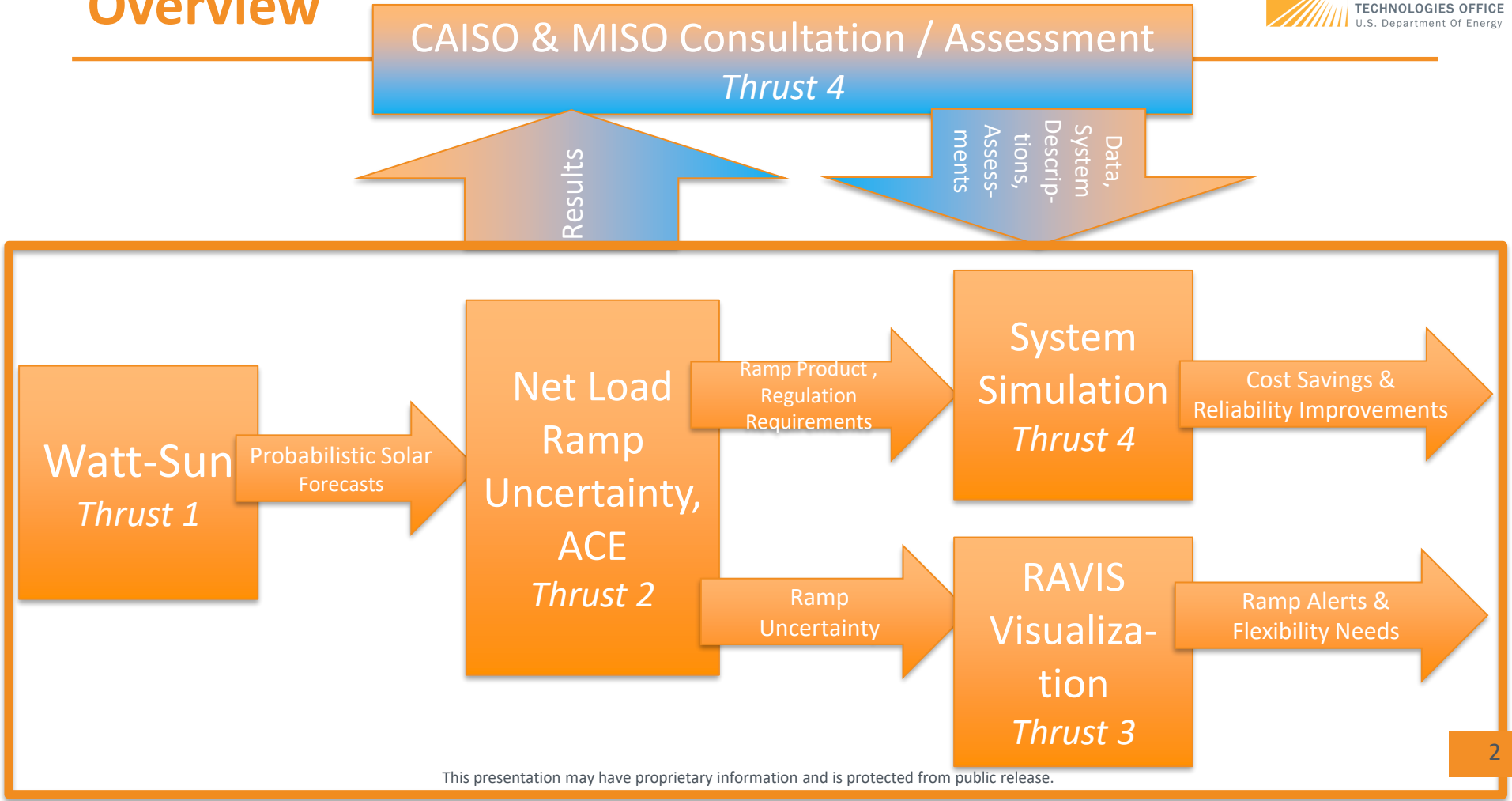
Overview



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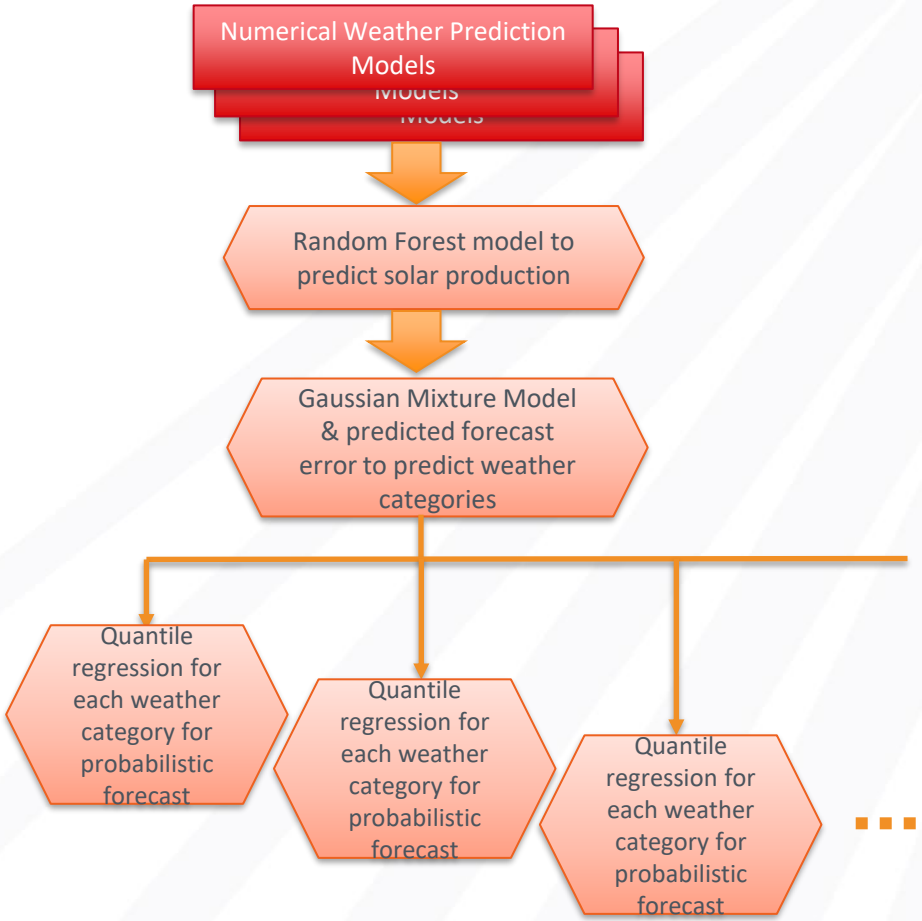
Outline

1. Comparison of Watt-Sun to base method: P-P index
2. Using solar forecasting prediction intervals to predict ramp & regulation: the Pareto method
3. Simulation of cost-reliability effects of solar-conditioned ramp requirements on CAISO system
4. Visualization: Resource Forecast and Ramp Visualization for Situational Awareness (RAVIS)

Probabilistic Watt-Sun Flowchart (IBM)



Used quantile regression to deploy probabilistic forecast models

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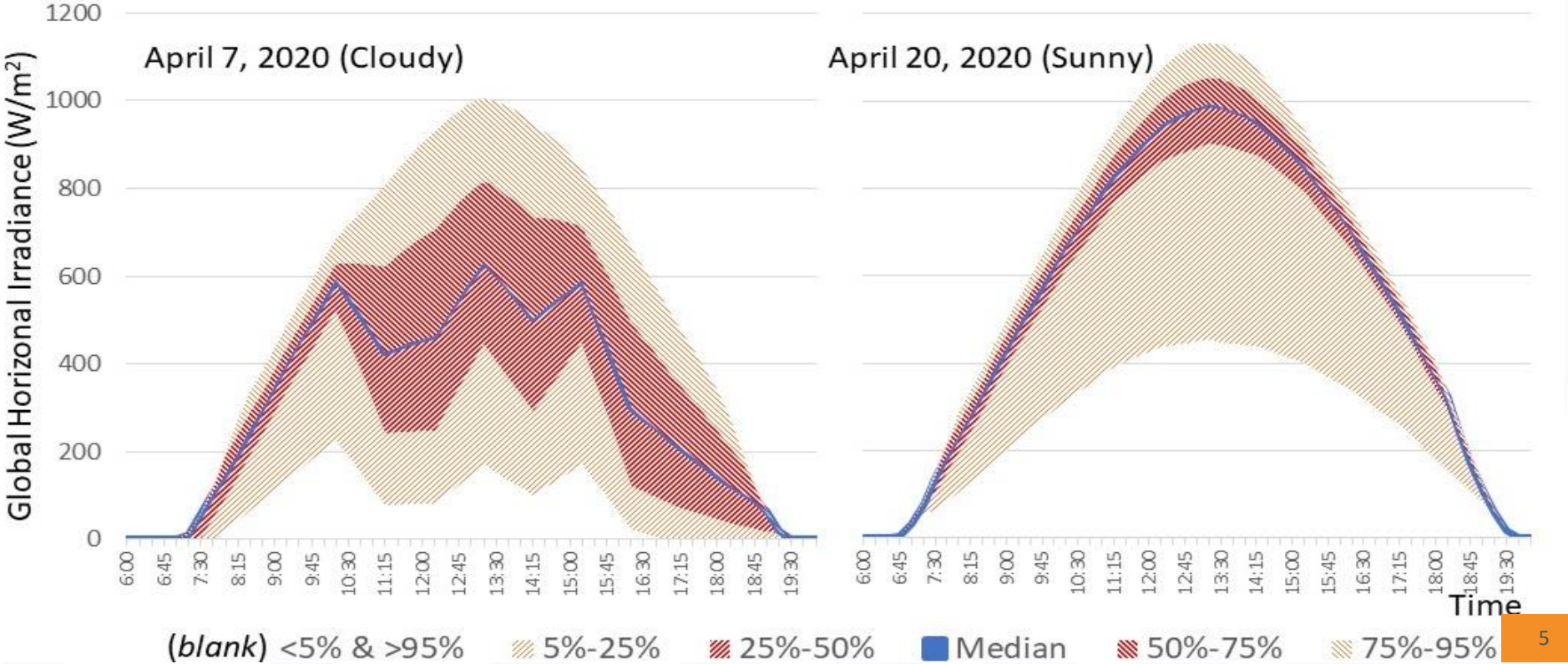
- Quantiles of solar as function of independent variables
- Example results for 2 hr-ahead forecasts



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Evaluation of Watt-Sun

Assessment: Relative Improvement of the PP-Plot Metric

Temporal

- Train: Sept. 1st, ‘18 - Feb. 29th, ‘20
- Test: Mar. 1st, ‘20 - June 1st, ‘20

Spatial

- 24 stations

Map: 24 reference stations

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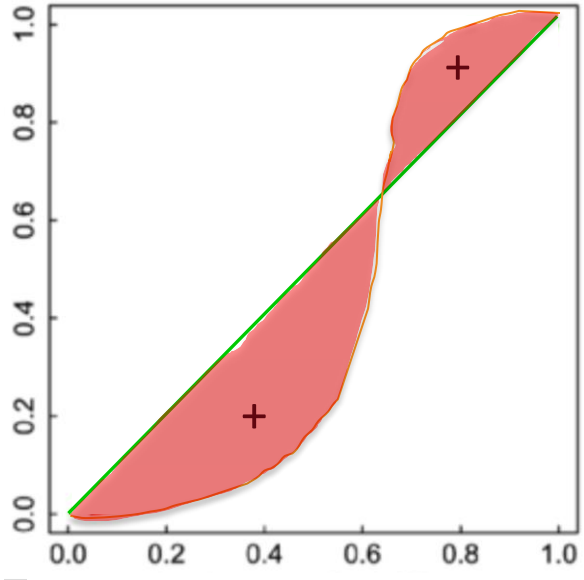
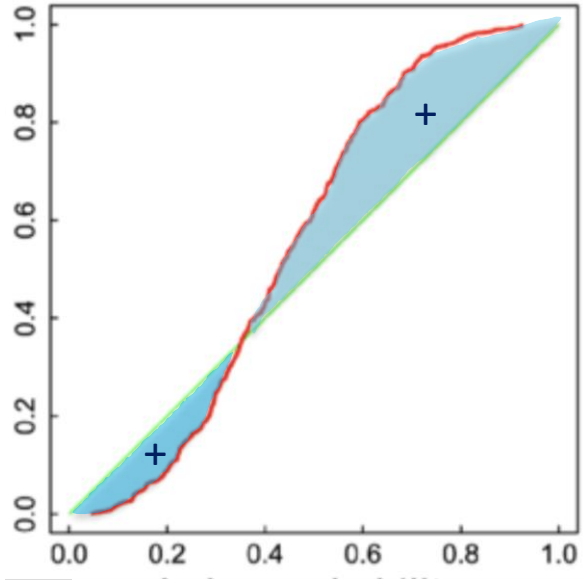
Calibration Quality of Watt-Sun vs. Persistence

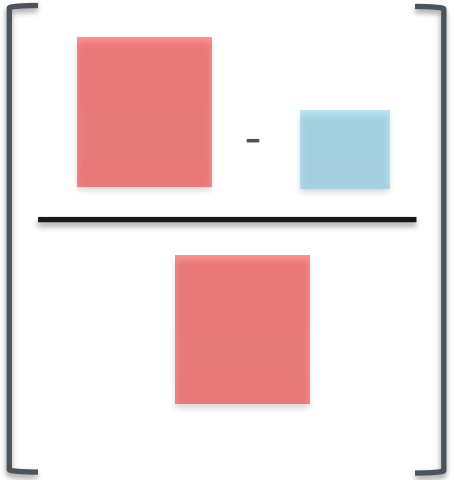
Assessment: Relative Improvement of the PP-Plot Metric



A. Baseline: PP-Plot



B. Watt-Sun: PP-Plot



C. Relative PP-Plot Metric Improvement of Watt-Sun

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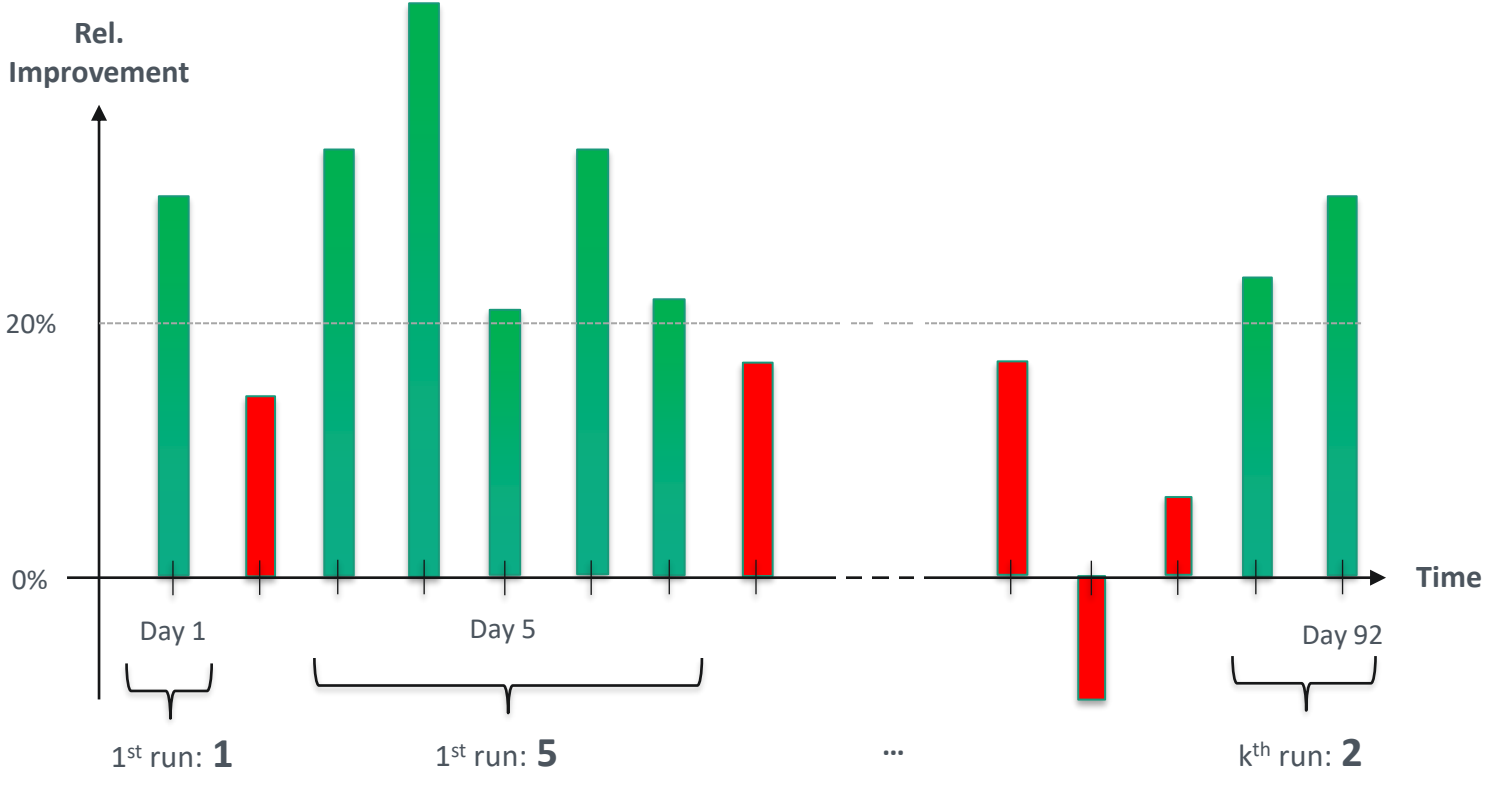
Daily Values of Metric

Assessment: Relative Improvement of the PP-Plot Metric



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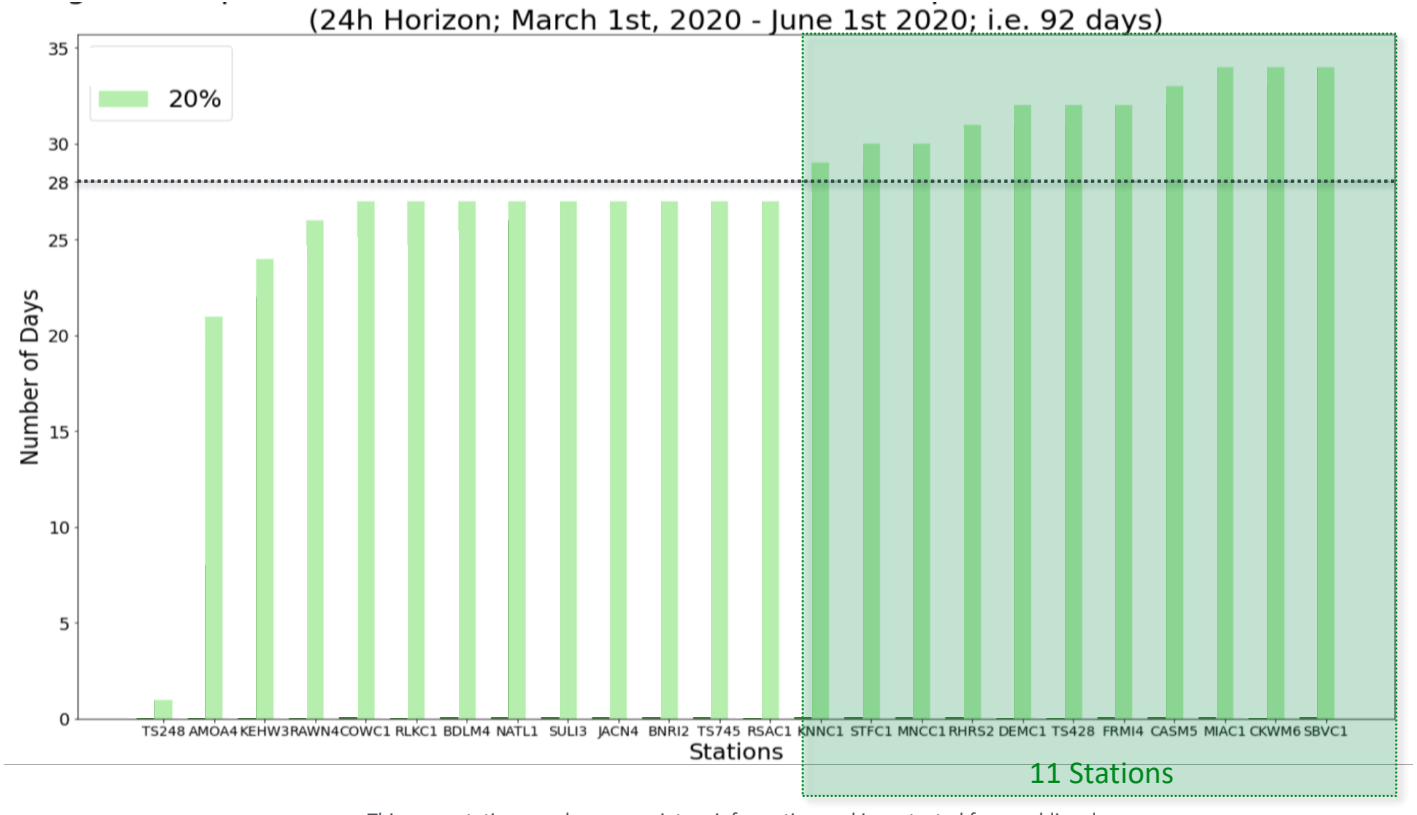
Longest Run per Station with Metric Improvement > 20%



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Flexible Ramping Product: CAISO, MISO, SPP

- CAISO: need to forecast three components in real-time:
  - Expected 5 minute ramp forecast
  - Uncertainty in up direction (97.5th percentile)
  - Uncertainty in down direction (2.5th percentile)
- Uncertainty distributions are presently unconditional
  - CAISO revising to condition requirements on wind, load, solar forecasts (www.caiso.com/StakeholderProcesses/ Flexible-ramping-product-refinements)

Quantile Analysis: Continuous classifier shows potential to adjust net load ramp "up uncertainty" (JHU)

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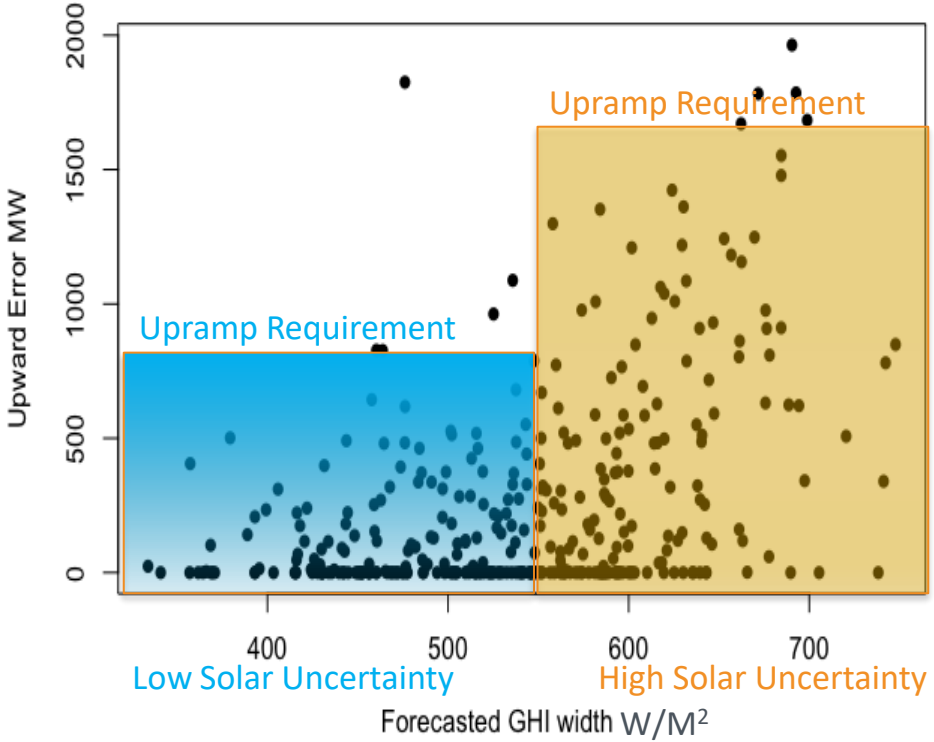
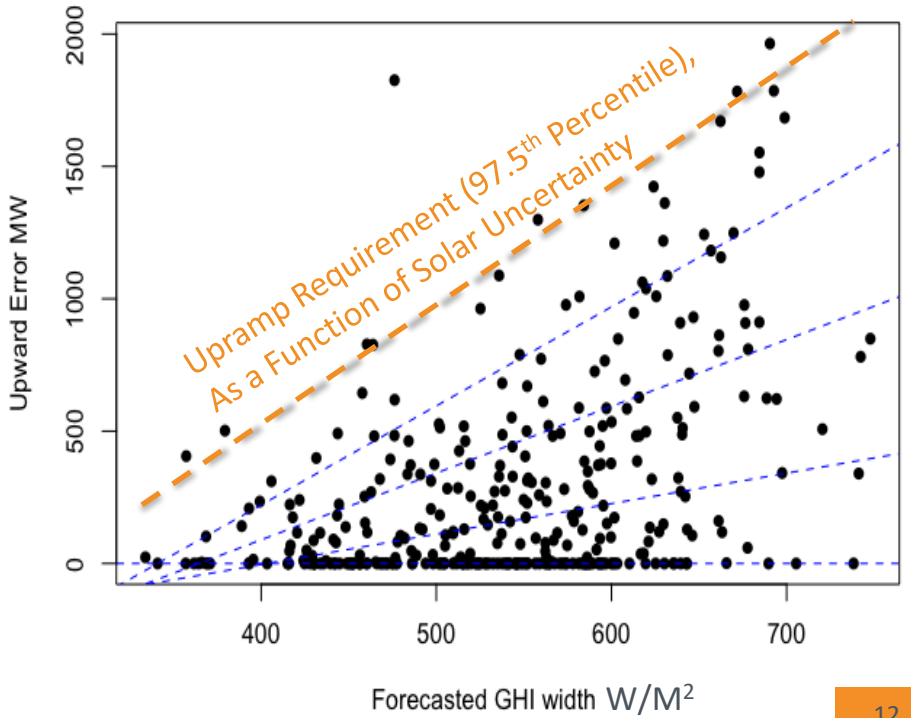
Two Way Classification Results
11 a.m.-2 p.m. May 2019:
97.5% Cutoff (Ramp Requirement) for Each Day Type



Upward Error Quantile Regression Results
11 a.m.-2 p.m. May 2019 (dashed blue lines are, from top to bottom respectively: 90th, 75th, 50th, 25th estimated percentiles)



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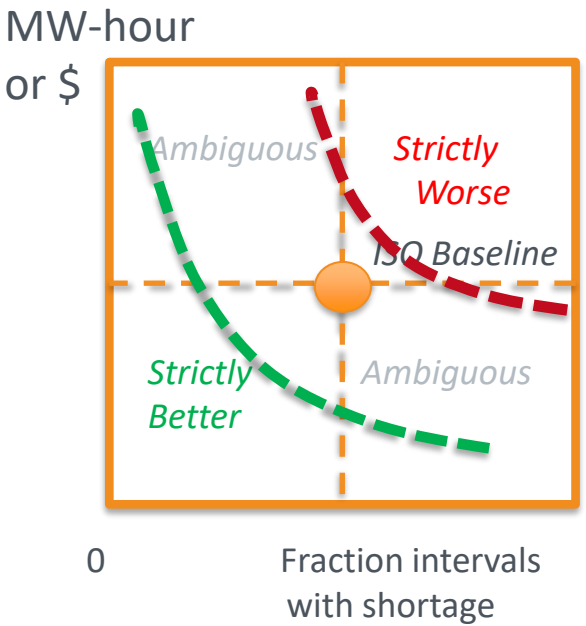
Out-of-Sample Pareto Analysis of Requirements

Methods:

- Compare performance of MW requirement method relative to ISO baseline method using multiple criteria
- Criteria:
  1. Reliability: fraction of intervals in which MW need exceeds requirement ("shortage")
  2. Cost: total MW-hour / $ cost of requirement
- Assessment procedure:
  - Simulate rolling estimation method (out-of-sample test)
    - Baseline: histograms of N previous days' realizations of MW need in that interval
    - Alternative: statistical or ML-based estimate of MW need
  - All methods: rescale amount or vary target reliability
    - Tradeoff: more requirements → less shortage but more cost



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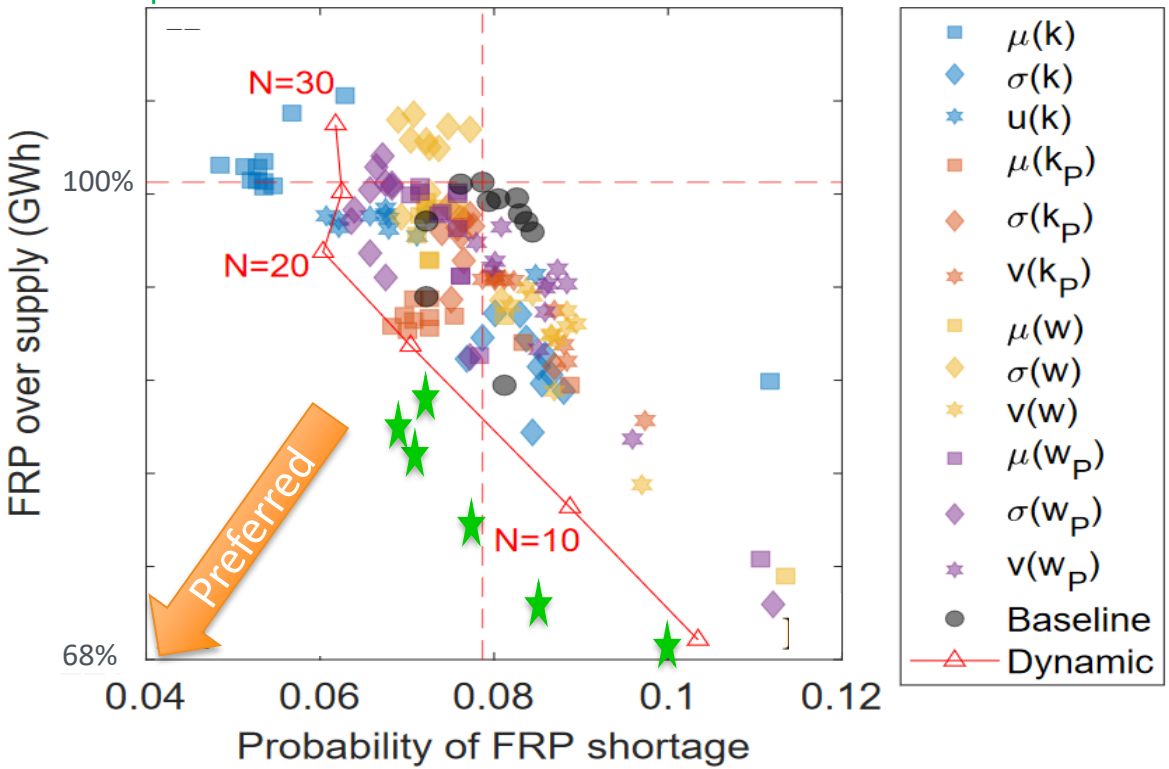
kNN/PCA-based Method for Flexible Ramp Requirements (UTD)

- Shown: kNN-based FRP requirements: Reliability-oversupply tradeoffs Feb. 2020.
  - 1-D classifiers from solar site 2 using various predictors
- Multisite/PCA classifiers perform even better



Out-of-Sample Pareto Analysis of Weather-Aware *Regulation* Requirements Using Solar Forecasts (JHU)

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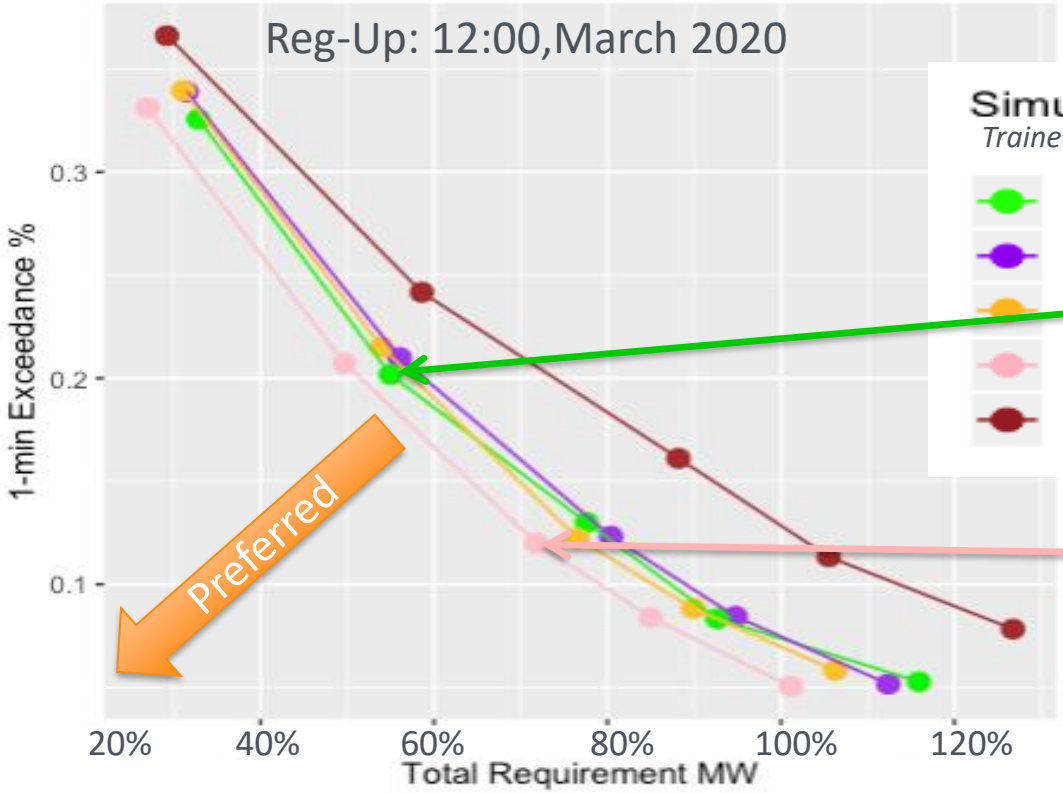
Quantile Regression-based regulation requirements: Tradeoffs between **reliability** (fraction of 1-min average adjusted ACE > requirement) & **MW supply**. (Unconditional and 1- & 3-variable rolling regressions)



Preliminary results:

- *ISO baseline method performs well*
- *Adding forecast variables sometimes improves*

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Benefits Assessment using Simulations (NREL)

FRP Analysis March 9-15: Baseline vs. New Flexible Ramp Requirements

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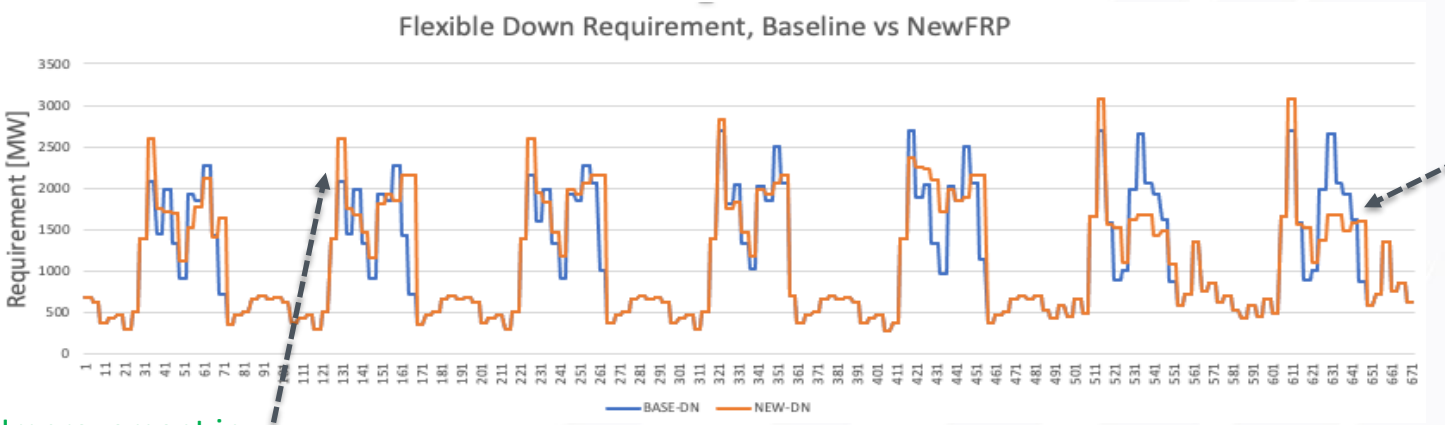
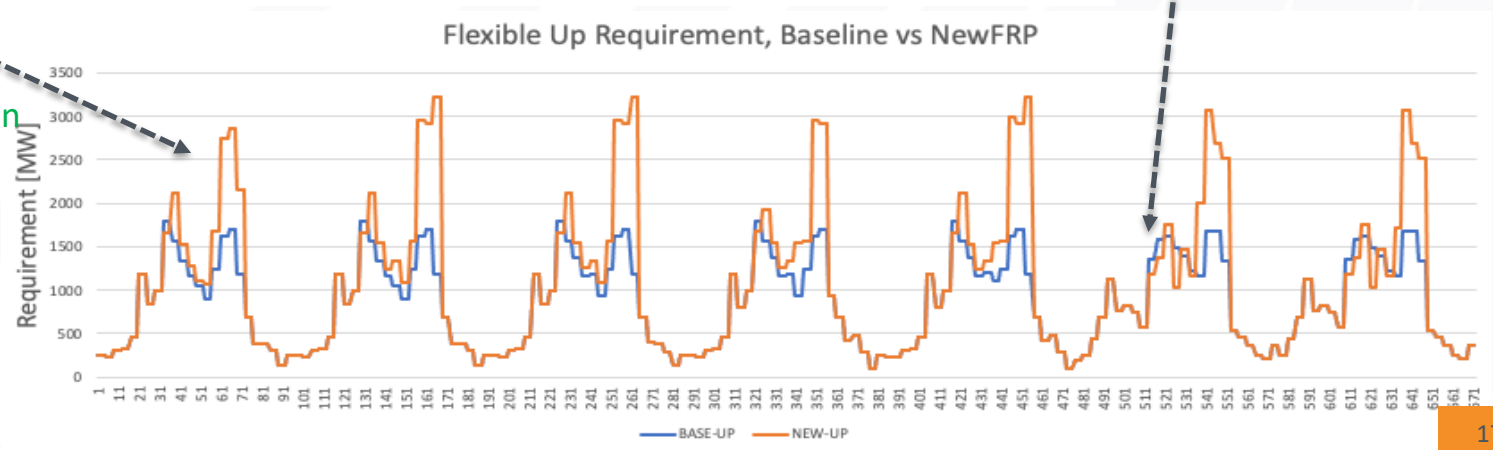


- Improvement in reliability
- Expected reduction in generation scarcity and price spike!
- Reduction in renewable curtailment



- Decrease in peaker units scheduling
- Reduction in production costs

Simulation Results – CAISO-like IEEE 118-bus System

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- FESTIV market clearing process modified with CAISO operating rules
- **IEEE 118 simulated for 3-weeks in March (9-29 2020):**

	Baseline (Scenario 1)	New FRP (Scenario 2)	Perfect NO uncertainty
Total Production Cost [$M]	23.45	23.05 *(1.7% savings)*	**23.00**
Total Uncertainty Cost [$M]	**0.45**	**0.05 *(~90% savings)***	

- Uncertainty induced costs reduced by a daily average of 44%
  - Savings in production cost from lower FRP (reduction in peaker units)
  - Higher FRP reduces generation scarcity events and real-time price spikes
  - More flexible generation, with lower min. gen → Reduced curtailment

Total VG Curtailment [GWh]	**69.1**	**63.9 *(more VG)***

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Results – Large 1820-node WECC / CAISO system

~1,820 buses: 1782 buses for CAISO and 38 for other WECC regions and trading hubs

Copper plate analysis

~$0.27M (1.7%) savings in uncertainty induced costs in 21 days

- $0.27M savings in 21 days ~ extrapolate to $4.7M/yr
- **~ $19.5K (12.7%) savings in FRP procurement costs ~ 340K/yr FRP cost savings**
  FRP clearing amount * FRP market clearing price (duals)

With full network

~$0.5M (~3.8%) savings in uncertainty induced costs in 21 days

- $0.5M savings in 21 days ~Extrapolate to ~$9M/yr, comparable to annual FRP costs
- Further simulation results forthcoming from HPC

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Open-source link to code: https://github.com/ravis-nrel/ravis

Resource Forecasts and ramp Visualization for Situational Awareness (RAVIS) (NREL)

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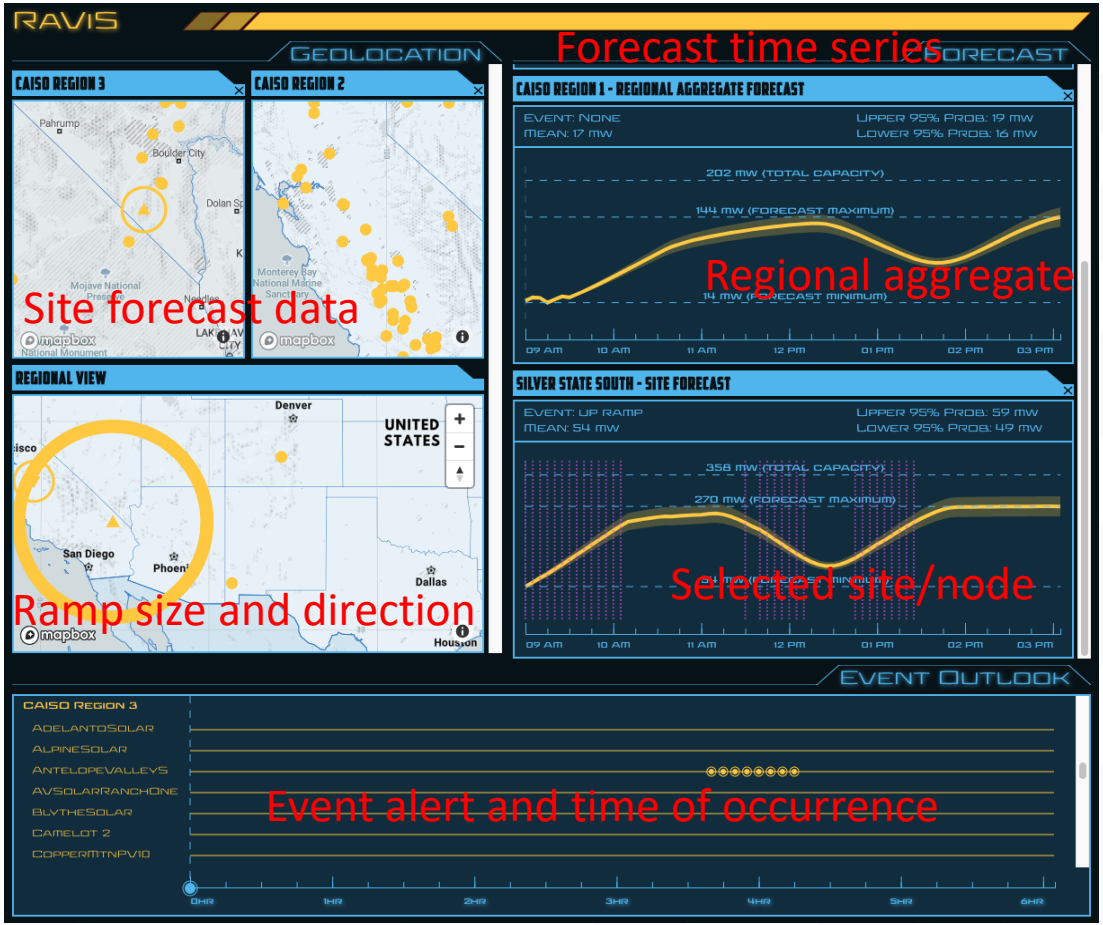

RAVIS: a modular dashboard for viewing:

- forecast timeline
- spatially relevant forecasts & events
- details of specific events as desired, including market data

Design: RAVIS's technology suite is assembled to ***provide optimum visualization facility***

- Takes ***advantage of web application technologies*** and tooling
- These technologies ***enable deployment in any environment***, using any operating system

…Can also show net-load time series forecasts and available generation headroom/flexibility

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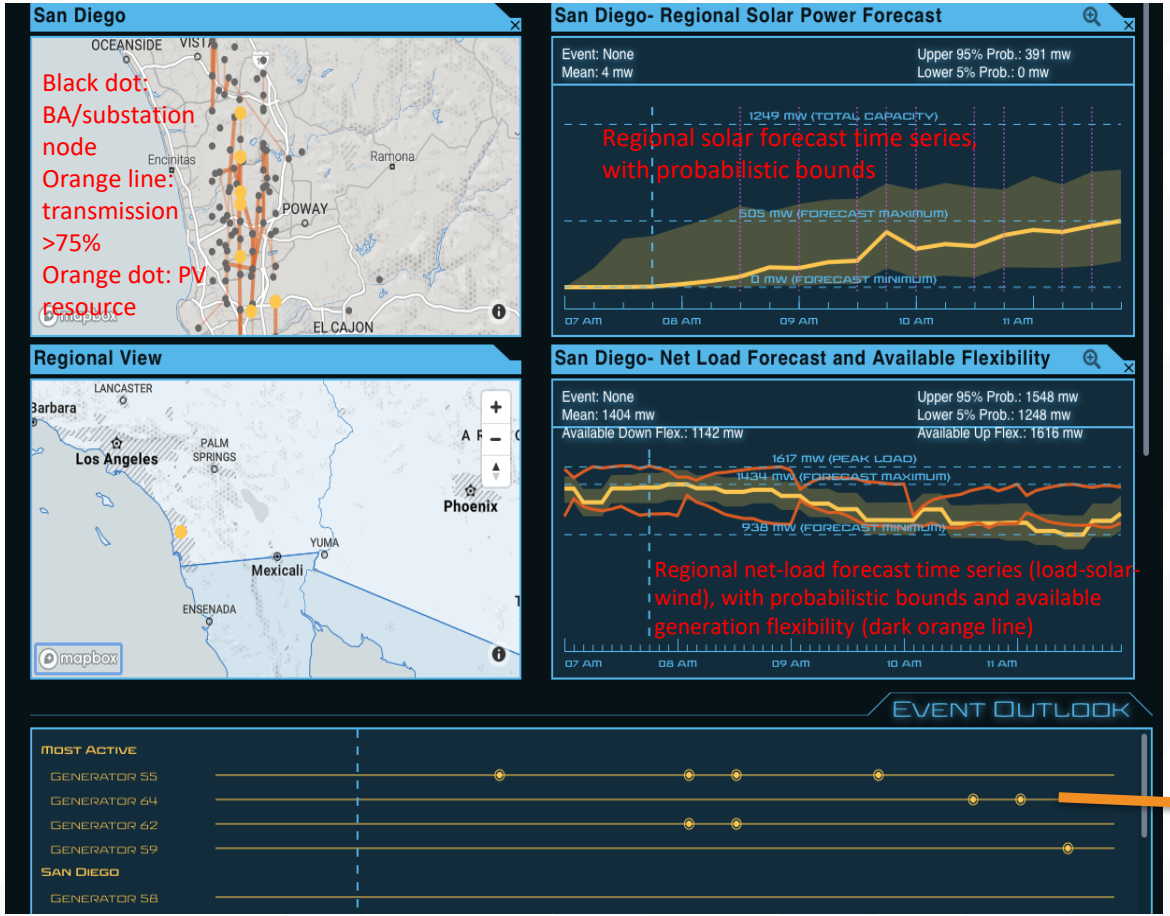

Flexible architecture to visualize more data:

- Net-load forecasts, or each component,
- Available generation flexibility,
- Network nodes,
- Transmission,
- Prices

Sorted ramp events: **“most active”** (e.g., most events in the next 5 hours)

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Summary of features visualized in RAVIS

1) **Site-specific probabilistic solar power forecasts**:

   Hovering reveals forecast data and other meta data; ramp size and direction are shown by circle and arrow

2) **Time series forecast data:** Clicking a site/region shows individual site-specific probabilistic forecast time series

3) **Event alerts (e.g., ramp alerts)**, at site as well as regional level

4) **User can configure visualization parameters**

   a) Specific sites or user-defined aggregate regions

   b) Ramp definition customizable by end user

5) **Data from market clearing engine integrated with forecasts viewer**

   a) **On map:** Network topology, nodal prices, transmission congestion

   b) **On time series:** Available generation flexibility, plotted against net-load forecasts.

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Open Source Publicly Accessible / Extensions

Extendable:

- Transmission & Distribution grids with Grid-edge visibility
- **Ongoing project:** Sensor data and cyber threats integration
  - (DOE CESER-funded project Situational Awareness and Grid Analytics (SAGA) project at NREL)

1) Open-source link to code: https://github.com/ravis-nrel/ravis

2) Documentation published@ https://www.nrel.gov/docs/fy21osti/79746.pdf.

P. Edwards, H. Sky, and V. Krishnan. 2021. *RAVIS: Resource Forecast and Ramp Visualization for Situational Awareness—An Introduction to the Open-Source Tool and Use Cases*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5D00-79746.

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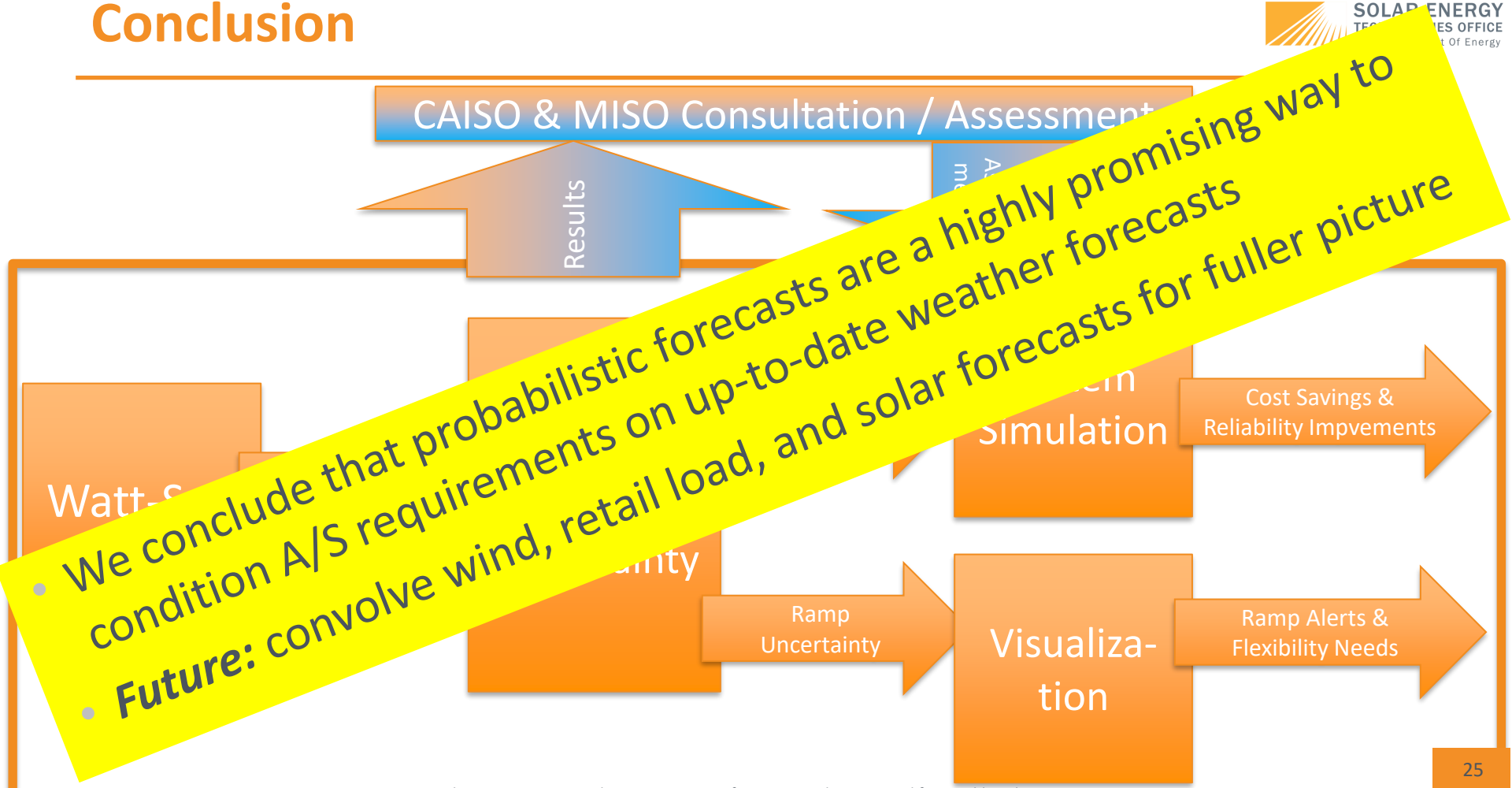
Conclusion



- We conclude that probabilistic forecasts are a highly promising way to condition A/S requirements on up-to-date weather forecasts
- ***Future:*** convolve wind, retail load, and solar forecasts for fuller picture

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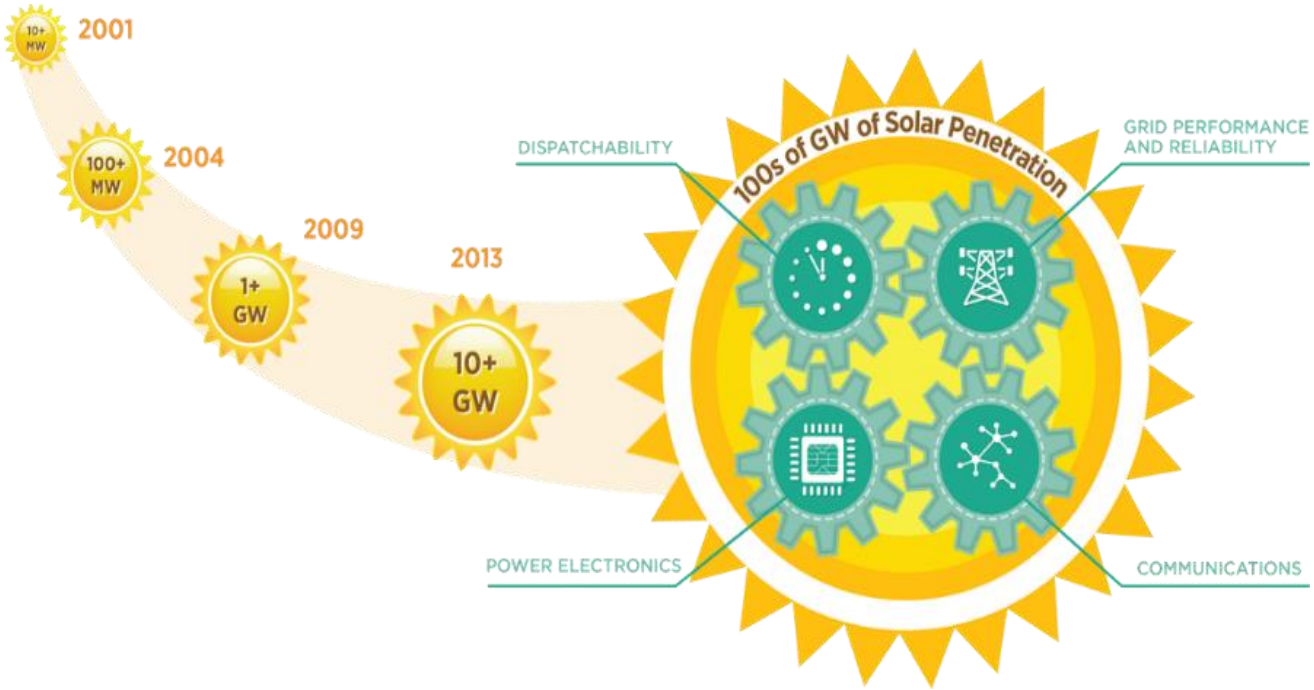
Questions?



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Backup Slides

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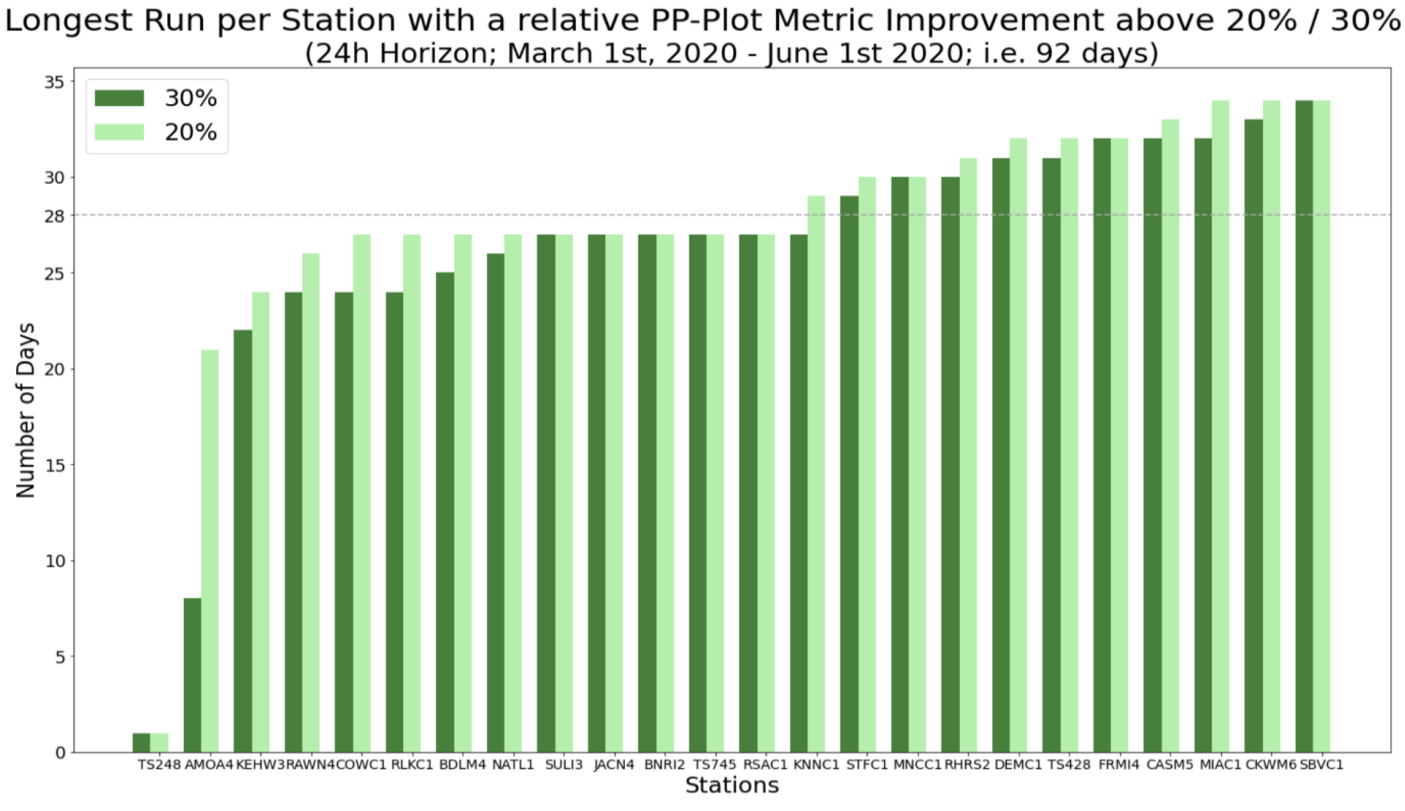
9.1A Continuous Improvements of Watt-Sun



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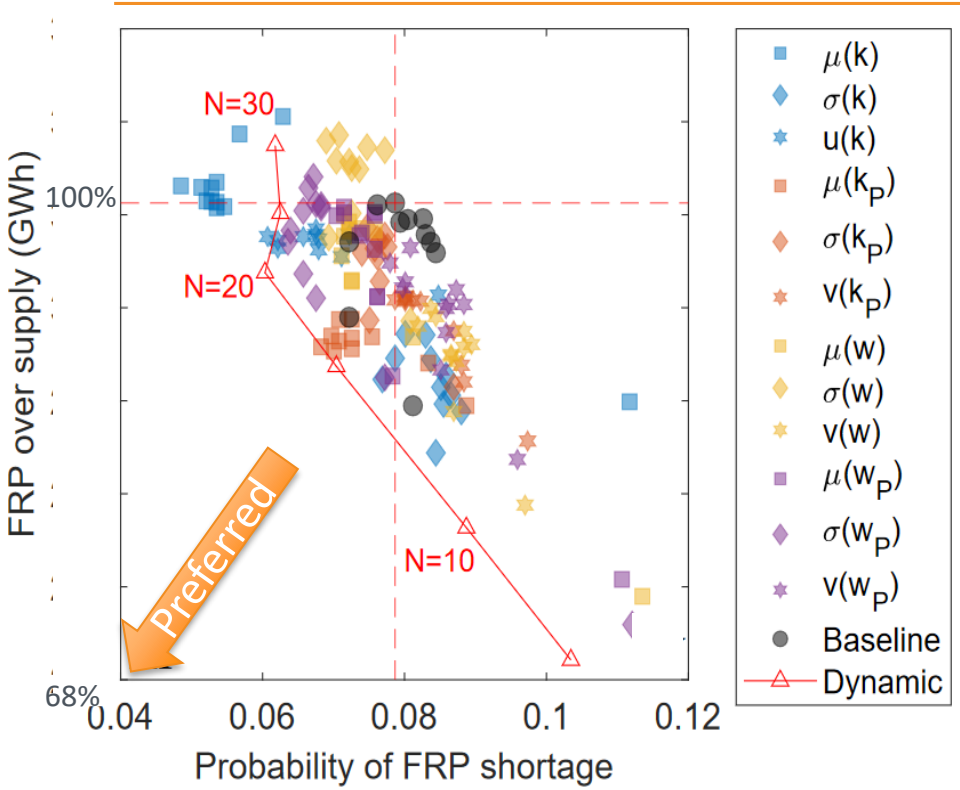
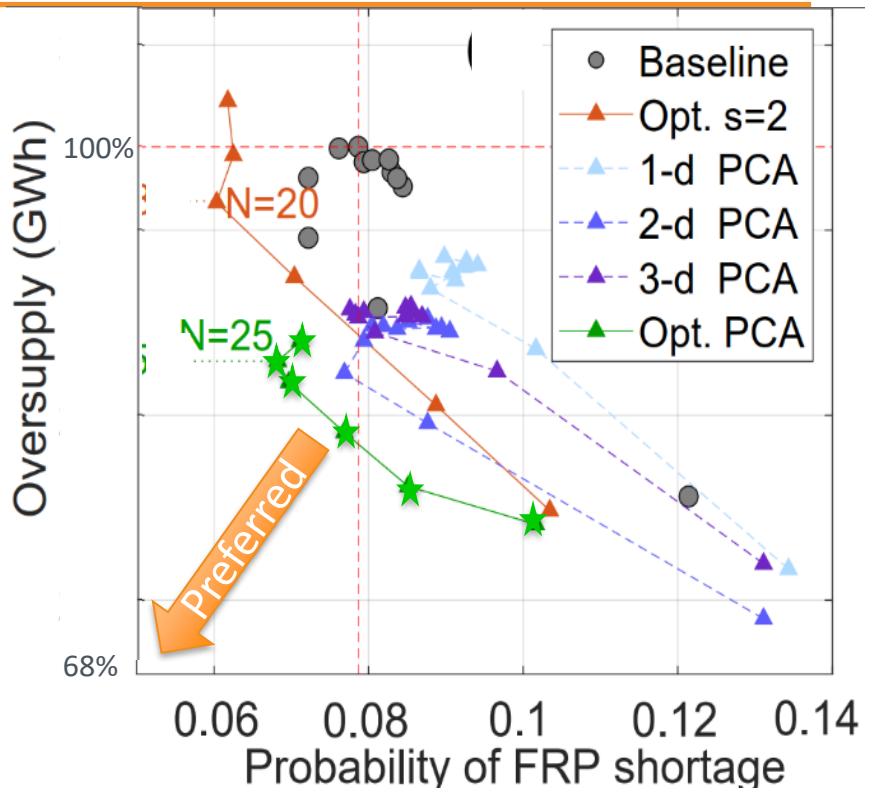
PCA/kNN-based Method for FRP Estimation (UTD)





kNN-based FRP requirements: Reliability-oversupply, tradeoffs Feb. 2020. (1-D classifiers from solar site 2 using various predictors)

PCA-based kNN analysis of FRP requirements from multiple sites